DEPLETION MODE POWER MOSFET WITH REFRACTORY GATE AND METHOD OF MAKING SAME

CROSS REFERENCE TO RELATED APPLICATION

This is a division of application Ser. No. 07/160,172, filed Feb. 25, 1988, now U.S. Pat. No. 5,472,888.

This application is related to copending application Ser. No. 1,629, entitled PROCESS FOR MANUFACTURE OF RADIATION RESISTANT POWER MOSFET AND RADIATION RESISTANT POWER MOSFET by Daniel M. Kinzer et al. and assigned to the present assignee.

BACKGROUND OF THE INVENTION

This invention relates to a method of manufacture of a depletion mode power MOSFET having a gate electrode formed of material that is refractory, or resistant, to high temperature encountered during thermal growth of oxide or any other high temperature encountered during device fabrication.

Material that is refractory, or resistant, to any high temperature encountered during device fabrication includes, for example, polysilicon; tungsten or other refractory metals; or titanium silicide or other refractory silicides formed from the known "polycide" process. For convenience, all such materials are referred to simply as "refractory".

Power metal oxide semiconductor field-effect transistors ("MOSFETs") are well known devices, and are typically used for power switching applications. As is known, a MOSFET includes source and drain regions of a first conductivity type, and a base region of a second conductivity type, which separates the source and drain regions. A conduction channel is formed in the base region to interconnect the source and drain regions and enable device conduction.

A depletion mode MOSFET uses a thin "depletion" channel region of the first conductivity type at the surface of the base region, which interconnects the source and drain regions. An electric field induced by a gate electrode above the depletion channel region empties such region of mobile carriers and thereby stops current conduction in the device. An enhancement mode MOSFET, on the other hand, does not utilize a channel layer of a first conductivity type beneath the gate electrode. Such device, instead, relies on an appropriate bias on a gate situated above the surface of the base region to induce an inversion channel in the base region, which conductively interconnects the source and drain regions.

The standard process for producing power MOSFETs is not applicable to depletion mode MOSFETs. In the standard manufacturing process, a highly-doped material, such as polysilicon, is patterned on the device to form a gate electrode. The gate electrode is then used as a mask to form a base region that is diffused at high temperature, such as 1175° C., for an extended period of time, such as 120 minutes. If the gate electrode is used as the base region mask, the depletion channel region must be formed prior to forming the gate electrode. The high temperature thermal drive used to form the base region, however, causes the thin depletion region to grow in thickness and to be harder or impossible to deplete with typical gate voltages.

One approach to prevent the depletion region from growing in thickness is to use a metal gate electrode rather than a refractory gate electrode. This is because metal can be

formed at a temperature that is relatively low and at which the depletion channel region does not grow in thickness. The resulting device, however, is complicated because two metal systems must be accommodated on the device upper surface: one for the gate electrode, and the other for the source electrode.

It would, therefore, be desirable to provide a method of manufacturing a depletion mode power MOSFET having a gate electrode formed of refractory material.

An additional drawback of conventionally-made MOSFETs is that their gate oxides are highly sensitive to ionizing radiation. Such radiation is known to induce charges in the gate oxide, which produces a shift in the gate-to-source threshold voltage. The gate-to-source threshold voltage decreases with increasing total radiation dose for N channel devices and increases with total dose for P channel devices. The gate drive circuitry must be designed to offset these threshold voltage shifts by overriding them with appropriate biasing levels. This complicates the control circuitry. A description of the shift in threshold voltage is described in more detail in a paper entitled "Radiation Resistance of Hexfets", contained at pages B-10 through B-12 of the Hexfet Databook of 1985, published by the International Rectifier Corporation, El Segundo, Calif.

It would thus be desirable to provide a power MOSFET having a gate-to-source threshold voltage that is close to constant regardless of exposure to radiation dosages up to 1 megarad, for example.

SUMMARY OF THE INVENTION

An object of the invention is to provide a depletion mode power MOSFET incorporating a refractory gate electrode, and to provide a method of making the same.

A further object of the invention is to provide a power MOSFET with a gate-to-source voltage that is nearly constant regardless of exposure to radiation up to 1 megarad, for example.

In accordance with a preferred process of manufacturing a depletion mode power MOSFET having a refractory gate electrode, a plurality of spaced base regions of one conductivity type are formed in a layer of semiconductor material of the opposite conductivity type. The base regions are formed by introducing into the layer dopant of the one conductivity type at selected locations on the surface of the layer. Such dopant is then thermally driven to a first depth beneath the surface by maintaining the semiconductor layer at a relatively high temperature for a given period of time. Thereafter, a plurality of source regions of the opposite conductivity type are respectively formed in the base regions. The source regions are formed by introducing and thermally driving dopant of the one conductivity type at selected locations on the surface of the layer. The source regions are driven to a second depth less than the first depth. An outer periphery of each of the source regions is spaced from the periphery of its associated base region.

Respective depletion channel regions are then formed in each of the base regions by introducing dopant of the one conductivity type into the upper portion of the base regions. This may be done by a blanket deposition of arsenic, for example. Thereafter, a gate oxide is formed over the depletion channel regions and is made as thin as practical. A refractory electrode layer is formed over the gate oxide and patterned to serve as the gate electrode. A dielectric layer is formed over the gate electrode, and a source electrode is formed over part of the source region. All process steps for forming the gate oxide and gate electrode, the dielectric